

Flow Control Actuation

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Outline

- Team Members
- Compressor Flow Control Overview
- Flow Control Actuation Systems & Experimental Results
- Fluidic Actuators
- High Temperature Shape Memory Alloy Actuators



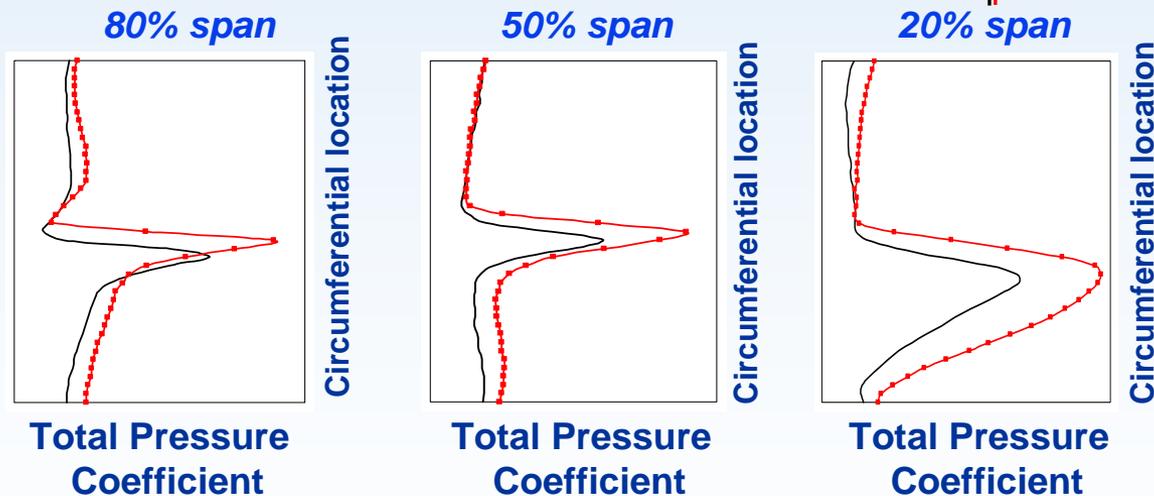
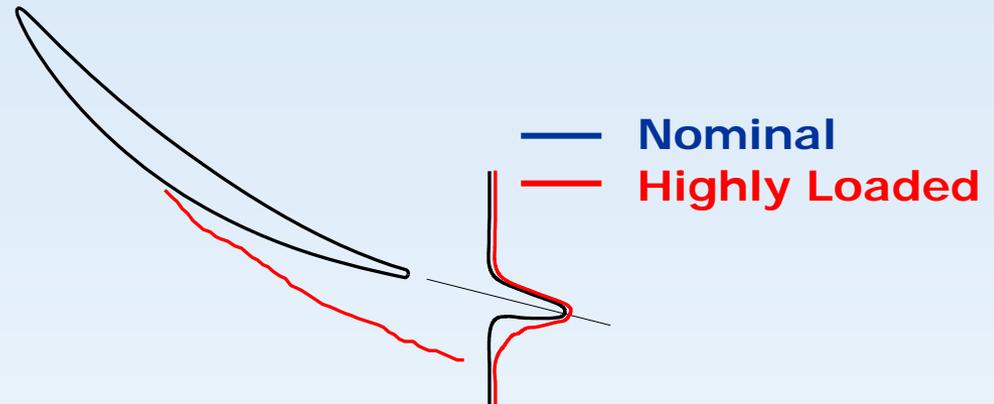
Team Members

Dennis Culley	Controls & Dynamics Branch
Randy Thomas	Controls & Dynamics Branch
Jon DeCastro	Arctic Slope Regional Corp (ASRC)
Doug Feikema	Combustion & Reacting Systems Branch
Suleyman Gokoglu	Combustion & Reacting Systems Branch



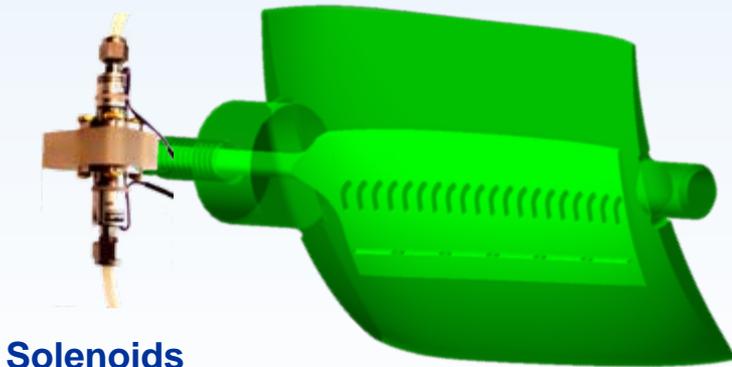
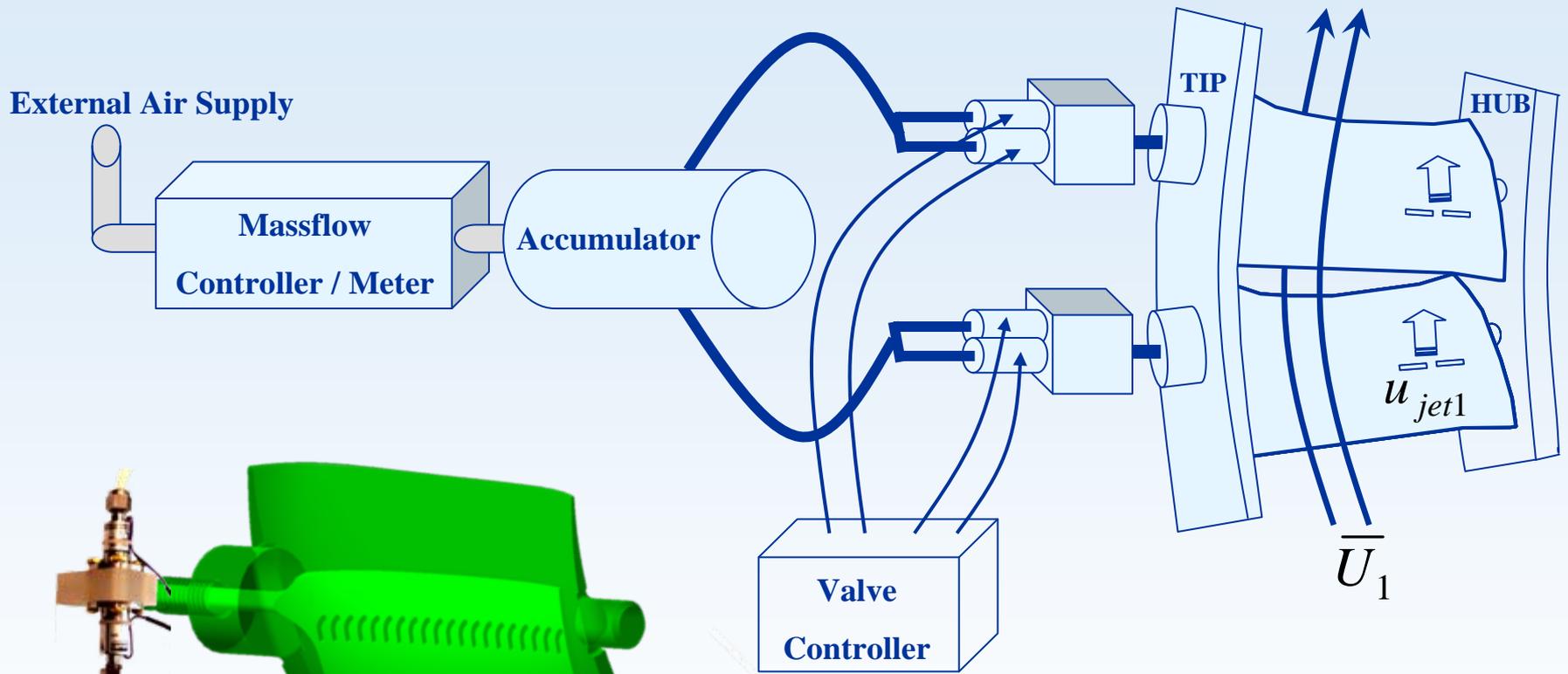
Compressor Separation

Suction surface separation is inferred from changes in wake width and depth



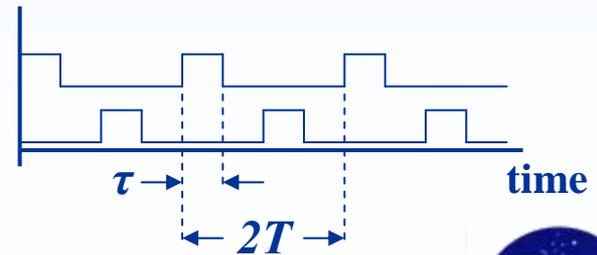
- Induce separation via blade stagger change and reduced flow coefficient
- Quantify separation by surveying total pressure (P_t) downstream of blades

Solenoid Actuation System

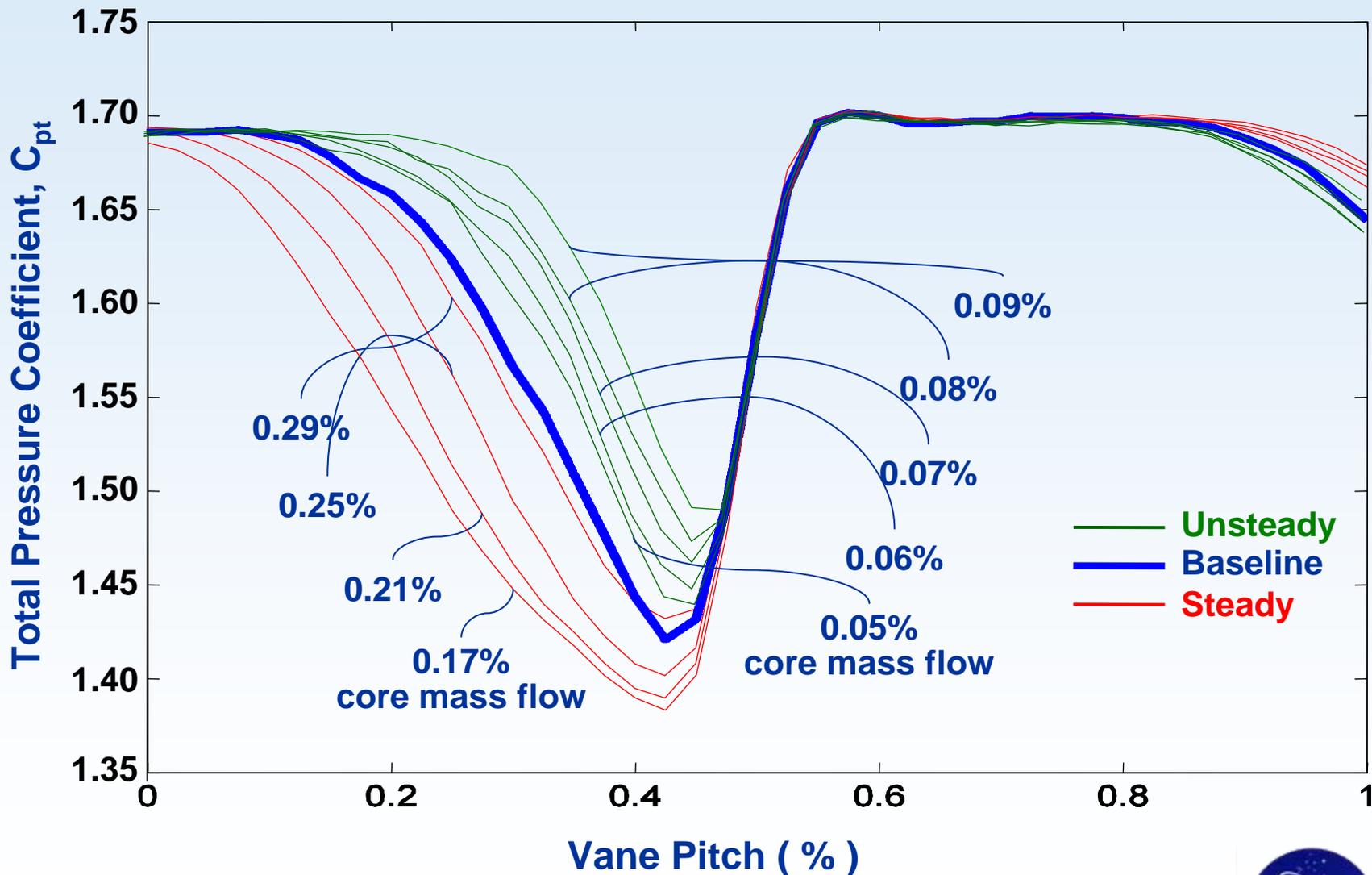


Solenoids with rapid prototype stator vane

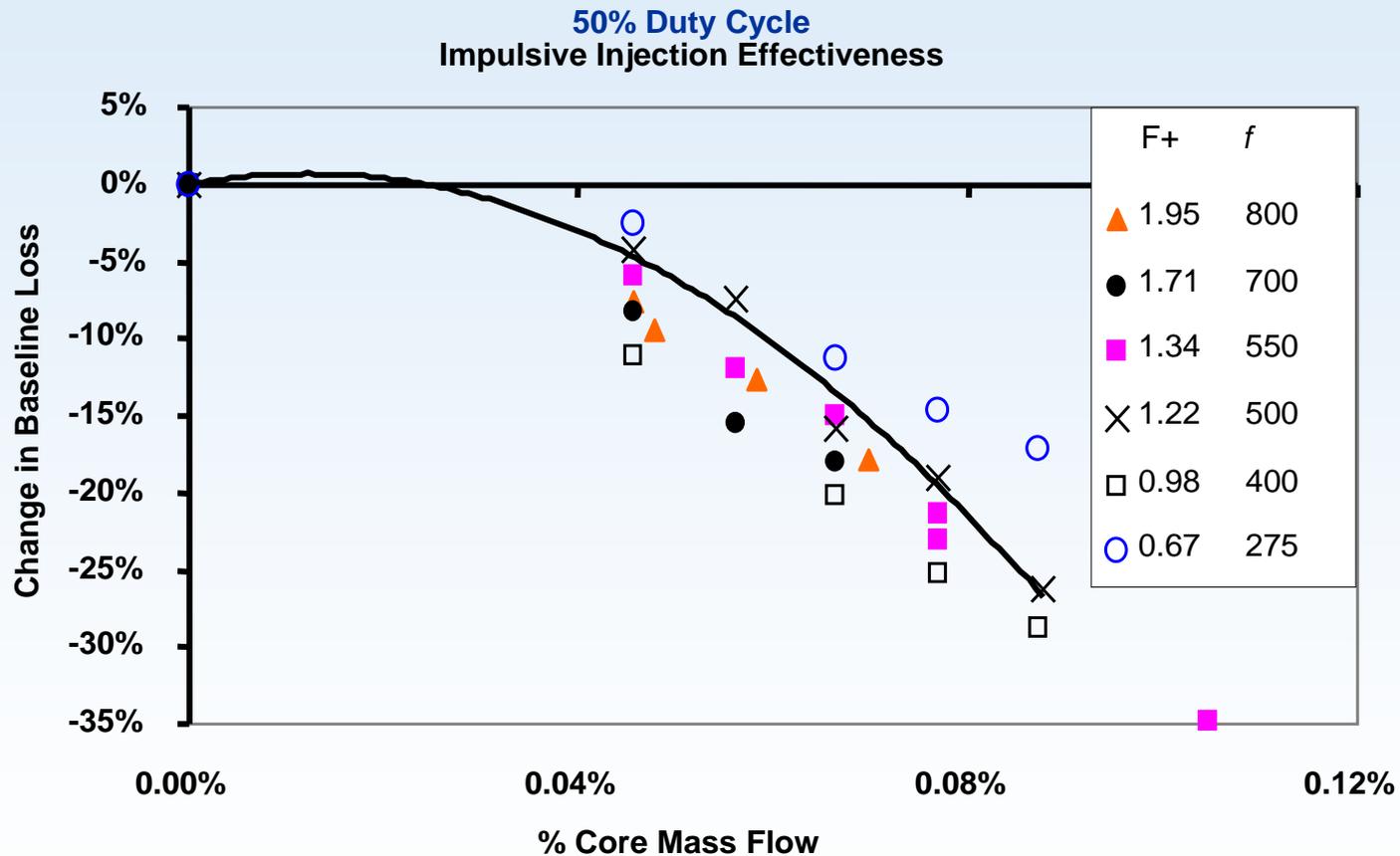
Interleaved valve signal



Steady vs. Unsteady Injection



Impulsive Injection in Compressor Stator



Flow Control References

A Study of Stall Control over an Airfoil Using 'Synthetic Jets', K. Zaman and D. Culley, NASA Glenn Research Center, Cleveland, OH, AIAA-2006-98, 44th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, Jan. 9-12, 2006

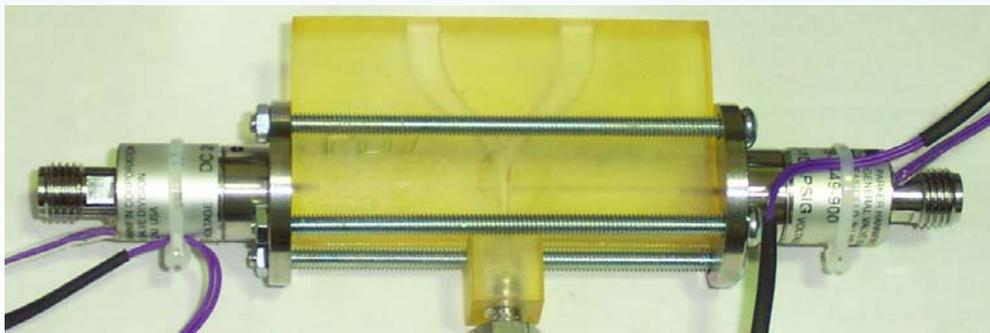
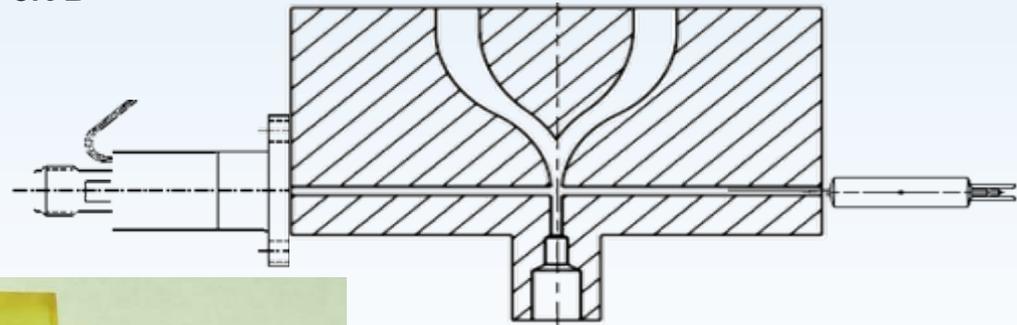
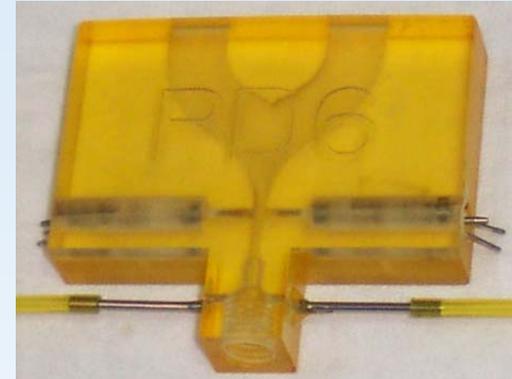
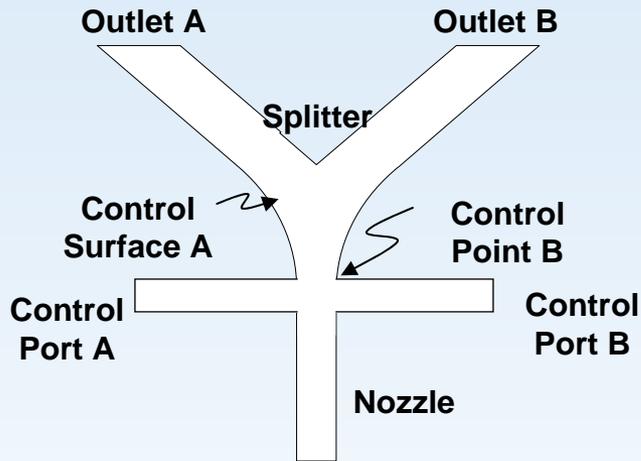
Separation Control in a Multistage Compressor Using Impulsive Surface Injection, D.W. Wundrow, Ohio Aerospace Institute, E.P. Braunscheidel, D.E. Culley, M.M. Bright, NASA Glenn Research Center, NASA TM- 214361, 2006

Impulsive Injection for Compressor Stator Separation Control, D. Culley, E. Braunscheidel and M. Bright, NASA Glenn Research Center, Cleveland, OH AIAA-2005-3633, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Tucson, Arizona, July 10-13, 2005

Active Flow Separation Control of a Stator Vane Using Embedded Injection in a Multistage Compressor Experiment, Culley, Dennis E. (NASA Glenn Research Center); Bright, Michelle M.; Prahst, Patricia S.; Strazisar, Anthony J. **Source:** *Journal of Turbomachinery*, v 126, n 1, January, 2004, p 24-34

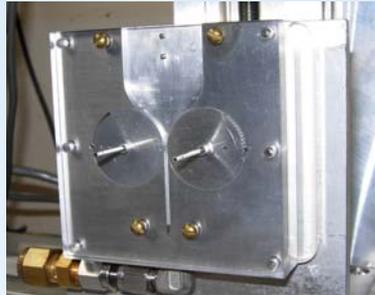
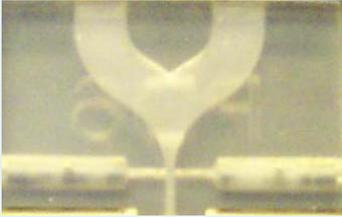


Actively Controlled Fluidic Actuators

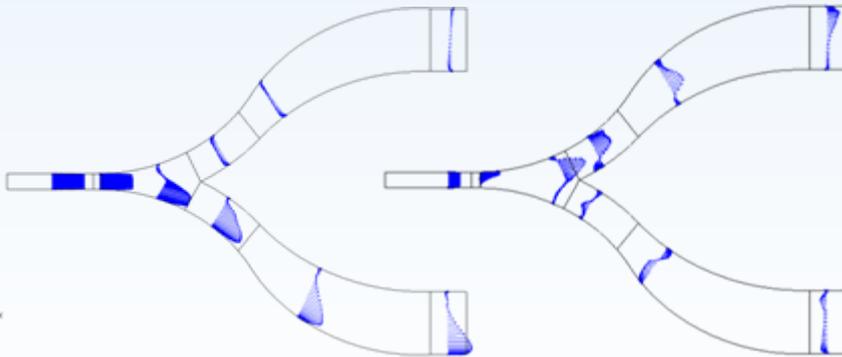


Rapid prototyped fluidic actuators with solenoid operators

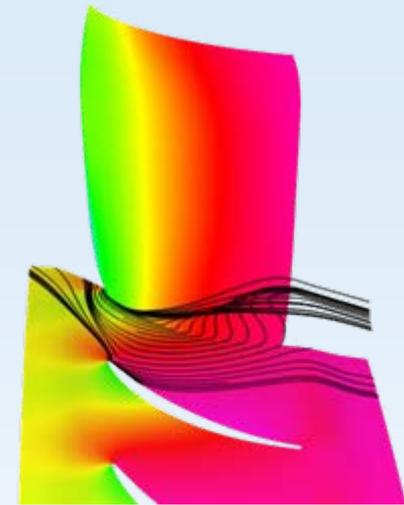
Current Efforts



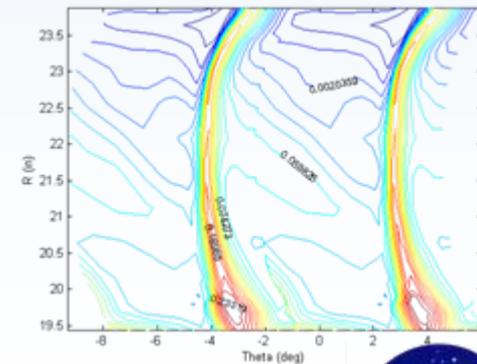
Plasma controlled
fluidic actuator



Modeling of the transient switching
performance of the fluidic actuator



SFW Turbomachinery Flow
Control task experiments
and analytical &
computational models



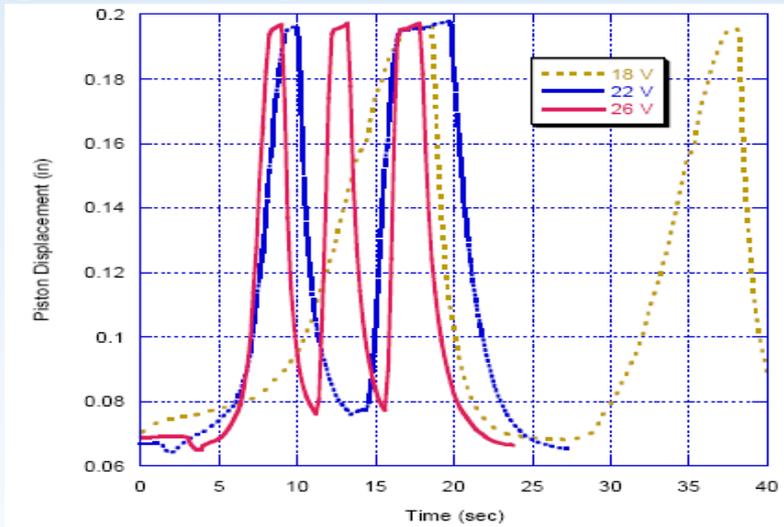
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High Temperature Shape Memory Alloy Actuators

Dynamic response of SMA actuators



HTSMA actuator developed for T700 engine



HTSMA actuator installed in T700 engine



SBIR success story
Miga Motors

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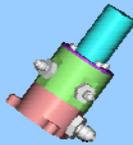
Active Flow Control Actuation Research & Development

**Component Rig
& Wind Tunnel Test**
- Separation Control
- Stability Control

Voice Coil



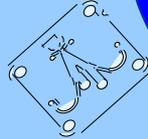
Rotary



Solenoid



Passive Fluidic



High Temperature
Shape Memory Alloy



Variable Frequency
Plasma-Fluidic



Rapid Prototyping



Actuator References

Development of a HTSMA-Actuated Surge Control Rod for High-Temperature Turbomachinery Applications, Padula, S, Noebe, R, Bigelow, G., Culley, D., et al, 48th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Honolulu, Hawaii, Apr. 23-26, 2007

Variable Frequency Diverter Actuation for Flow Control, D. Culley, NASA Glenn Research Center, Cleveland, OH, AIAA-2006-3034, 3rd AIAA Flow Control Conference, San Francisco, California, June 5-8, 2006



Opportunities for Collaboration

SFW Funded Opportunities

Currently there are no funded opportunities within SFW

Collaborative Opportunities

Fabrication and micro-machining

Materials development

Electronic circuit development and miniaturization

Electric and magnetic field analysis

Computational fluid dynamics (CFD) model development

Experimental applications and testing

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Future Plans

Continue the effort to develop, expand, and refine techniques for active flow control in aero-engine applications through multi-disciplinary collaboration.

Goals

- Through improved understanding, develop the **design tools** which will enable the practicable use of flow control in a wider breadth of aero-engine applications.
- **Deliver realistic and reliable actuation technologies** for embedded, point-of-use flow control in the aero-engine environment.

